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ABSTRACT

Electroencephalogram and task performance data were collected from three groups of young adult males: profoundly deaf Ss who signed from an early age, profoundly deaf Ss who only used oral (speech and speedreading) methods of communication, and normal hearing Ss. Alpha and Beta brain wave patterns over the Wernicke's area were compared across groups by task. Differences in brain activities patterns were observed between deaf and normal as well as between signer and oral deaf Ss. These results suggested a difference in brain organization across groups. Hemispheric difference in brain activation was observed only for the Mooney faces task. Findings indicate that if deaf persons have consistent error-free language codes early enough in life they could develop near-normal cognitive abilities. (Author/CL)

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EEG Alpha and Beta Activity

in

Normal and Deaf Subjects

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EEG Alpha and Beta Activity in Normal and Deaf Subjects

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Abstract:

EEG and task performance data was collected from three groups of young adult males: profoundly deaf who signed from an early age, profoundly deaf who only used oral (speech and speedreading) methods of communication and normal hearing persons. Alpha and Beta brain wave patterns over the Wernicke's area ($P3\text{-}T_5$) were compared across group by task. Differences in brain activities patterns were observed between deaf and normal as well as between signer and oral deaf persons. These results suggest a difference in brain organization across groups. Hemispheric difference in brain activation was observed only for the Mooney faces task.

Background

Educational programs for the prelingually profoundly hearing impaired emphasize spoken (English) language during the formative years, often to the exclusion of problem solving, logical thinking and reasoning using alternative sense modalities. The premise was that English (spoken) language is a precursor for these skills.

Research into perceptual strategies has provided evidence that there may be inherent differences between hearing and deaf. Contrary to the traditional belief that these differences occur due to a developmental lag in the deaf persons it is now widely believed that there are developmental differences owing to different sensory feedback modulities which are available to the prelingually deaf person (Freeman, Carbin & Boese, 1984; Waldron, 1982). The sensory mechanism used in acquiring and coding information probably leads to different cortical organization. If this is so then are there inherent hemispheric differences or are there different cortical resources used in cognitive processing of hearing and deaf persons?

To answer these question several authors have looked at organizational differences for deaf and hearing. Phippard (1977) found that there was a right hemisheric advantage (RHA) for both verbal and nonverbal tasks for orally trained adolescents and no asymmetries for those who used total communication. She found lateralization between deaf and hearing persons, this was more marked for the older age children. Ashton & Beasley (1982) found more left hemispheric advantage (LHA) for the hearing persons to English tasks. Conlin & Paivio (1975) found that both deaf and hearing subjects used imagery mediators for high imagery pairs. However, signability of words facilitated recalls only for deaf subjects. A gestural sign strategy for sign-signability pair was reported exclusively by the deaf subjects. They

suggested that an examination of effects of sign language variables may shed light on the qualitative differences in the associative learning of deaf and hearing subjects. Neville & Bellugi (1978) in studying deaf natives signers found that a significant LHA existed for unilateral dot lateralization task whereas the hearing controls exhibited the expected RHA to this task. Handedness preferences for spatial haptic tasks were studied by Cranney & Ashton (1982). They found inconclusive evidence on lateralization studies. Evoked potentials were studied for group differences by Neville (1978) on figure reproduction tasks. She found right-hemisphere advantage in visual evoked potentials for the hearing where as a left-hemispheric advantage for signers and no hemispheric advantage for the oral deaf.

Very limited study exists in examining learning style and cognitive differences that may exist when subjects are actively engaged in solving visual-spatial problems (Poizner & Battison, 1980). Since deaf persons use predominantly visual sense in acquiring information, a study of this approach to solving spatial problems should provide valuable information on relation of language and cortical functions. It was reasoned that if indeed for successful interpersonal communication the majority of prelingually deaf persons use some form of sign or gestural language, their language development must use some visual spatial processing. Further, if it is correct that Wernicke's area is primarily responsible for processing auditory images and hence English (heard & spoken) language then one must ask what happens to this area in people where auditory image is unavailable especially during prelingual years (Heilman, 1978)? Waldron and Rose (1984) proposed a nonlinear feedback model where they postulated that the brain for the congenitally profoundly deaf persons is substantially reorganized both structurally and functionally. They further suggest that for this population

Wericke's area is probably accessible by visual tactile sense through the associative cortical pathways. The present study was designed to study this hypothesis.

The Experiment and Protocol

The present study is a pilot study to investigate this reorganization further. In this study the observation that the alpha band power decreases with cognitive processing is utilized. While performing cognitive tasks specifically visuo-spatial, the normal right handed subjects showed more right-hemispheric activity. The two visual spatial tasks which were used were pattern recognition and Mooney Faces. Mooney (1956) developed a means of measuring psychological closure by using a set of incomplete pictures of human faces. These faces were presented by the experimenter. For the response of this task, APPLEII+ video screen was divided into two halves. The subject placed the cursor on the left or the right half depending on if he thought the face was a man's or a woman's. The pattern recognition tasks were developed for the APPLEII+ microcomputer (see Figure 1 for a sample task). Both tasks were presented to the subjects so that the subjects' response pattern was to move the joystick and locate the cursor on their selected response. Since all tasks presented had this same response, it minimized the muscle artifact across tasks and subjects. The subjects were trained on the tasks using whatever mode of communication they had available. The training lasted until the subject felt comfortable that they could respond correctly to the tasks at hand. The base line data was determined by asking the subject to stare at a dot on the screen. The order of task presentation was collection of baseline data then a 2-minute break, Mooney faces presentation, a 2-minute break and the pattern recognition task, etc. The tasks were replicated in reverse order of presentation.

The subjects consisted of six normals, 7 orals (who primarily used lipreading and speech for communication) and 6 native signers (who had learned sign language before the age of seven years). Their mean chronological age was 25 years for normal and signers, and 22 years for the oral deaf. The mean hearing loss for the deaf subjects in the speech range was 80 dB for the oral subjects in the and 97 dB for the signing subjects. After the subjects were trained to a preset level of performance, a set of tasks labeled test were presented. To ensure that the subjects were actively engaged in the cognitive task 75% or better performance was solicited for each task. While the subjects were actively engaged in the task, EEG data was collected over Wernicke's area (P3-T5) and the corresponding right hemispheric leads (P4-T6) for a minute and four seconds. A cap with standard electrode placement techniques with an ear clip ground at the right ear lobe was used to collect the data. The signals were amplified; converted to FM and recorded on a cassette recorder.

The recorded data was analyzed by demodulating the signal and filtering it up to 40 Hz. The data was sampled at 100Hz and analyzed using the Fast Fourier Transform techniques on a PDP 11/45 minicomputer. The frequency spectum consisted of power in 8-12 Hz (Alpha) and 13-40 Hz (Beta) frequency bands for one minute EEG signal epoch for each task and subject. The Beta and Alpha band ratios were then computed.

Results and Discussion

The data collected was analyzed using the analysis of variance for the subject type by task. The result of this analysis are shown in Table I. In this table the values of Alpha, Beta and the ratio are the mean values for two replications. The base line was taken as a task. No significant differences were observed at $p<0.5$ level between groups. However, it was noted that the

base line values themselves were very different (Figure 2). Hence analysis of covariance was performed with base line as the first covariate. The results of this analysis are shown in Table II. Significant group differences (at $p<0.05$, $F=4.44$) were observed for the pattern recognition task. Significant hemispheric differences (at $p<0.05$, $F=5.04$) were observed for the Mooney faces tasks. However, between the orals and signers significant group difference were observed for both Mooney faces ($p<0.05$, $F=8.55$) and pattern recognition task ($p<0.05$, $F=5.84$) and significant hemispheric differences were observed for the Mooney faces task ($p<0.05$, $F=9.52$).

For Mooney faces tasks there was considerable more activity in the right hemisphere for the oral deaf than for either signers or normals. For pattern recognition tasks there was more activity in the left hemisphere for both the normals and the signers whereas the oral deaf continued to show greater right hemispheric activity. Looking at Figure 2 one notes that the base line activity is very similar for the normals and the signers. Both represent more left hemispheric activity. However, for the oral deaf there is almost no activity even in the left hemisphere, but the three groups have almost the same level of activity over the right hemisphere.

Noting that base line data was collected when the subjects stared at a dot with their eyes open and were not engaged in any formal cognitive activity; this result suggests that signers and non-signers have similar base activity pattern over Wernicke's area. Irrespective of the tasks signers exhibited greater cortical activity than either oral or normal deaf. This may be due to the fact that visual information being spatial requires more memory storage and inherent resources. Those persons who have used sign language since prelingual years may have integrated information requiring more cortical activity than the efficient auditory channels as for normals. Both normals

and signers showed similar slopes (in Figure 2) between left and right hemispheres for both cognitive tasks. Whereas orals crossed. These results are consistent with Neville's (1978) work using visual evoked potentials, where she found evidence of cerebral specialization in normal and signing deaf but none in oral deaf persons.

One can interpret these results in the light of the cortical model proposed by Waldron (1983). Vision is primarily based on charemic code (Stokoe, 1976) which involves two and three dimensional spatial coding along with temporal code. Whereas auditory phonemic coding which is primarily temporal in code. Waldron & Rose (1984) proposed that the brain in prelingually profoundly deaf pesons is reorganized so that the visual language is developed predominantly through the visual sense. They contend that by giving sign language early enough, neural pathways can develop which can access the linguistic area (normally reserved for the auditory sense) through the associative cortex. For the oral deaf no consistent feedback path is available suggesting limited use of linguistic area.

In examining the Mooney face task more closely it is observed that cognitively the task requires not only gross visual classification but also requires a linguistic classification of man or woman. This would explain why both left and right hemispheric tasks are evenly represented during the performances of this activity, whereas the oral deaf show no linguistic pass into the left hemisphere. For pattern recognition task one starts to get into visual thinking. Both normals and signers showed more left hemispheric activity which was contradictory to the oral population. However, the level of activity was much higher for the signers than normals which may be due to the inefficiency of the alternative sensory process through the associative cortex.

The educational implications of this study are many. Because of the similarity in the cortical activity one can postulate that the deaf persons if they have consistent error free language code early enough in life they could develop near normal cognitive abilities. Hence, in the area of problem solving, logical thinking and deduction process the symbolic-visual-spatial aspects of their language could be efficiently used to make them proficient in these skills. This area has been neglected in the deaf education owing to the erroneous assumption that the aduitory language with its syntax (English) was essential to be a successful problem solver and abstract thinker. This study indicates that much more research needs to be done to find alternative ways of teaching these cognitive skills.

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TABLE 1. Results of Analysis of Variance

Log of Alpha, Beta and Beta/Alpha activity by subject type and task (N = normal, O = oral, S = signers) Average of two replications

Task	sub type	Log Alpha Power Left Hem.	Log Alpha Power Right Hem.	Log Beta Power Left Hem.	Log Beta Power Right Hem.	Log (Beta/alpha) ratio Left Hem.	Log (Beta/alpha) ratio Right Hem.
Baseline	N	.83	.91	1.06	.86	.23	.15
	O	.95	1.02	.98	.95	.05	.11
	S	.14	.93	.40	.93	.27	.15
Mooney Faces	N	.57	.72	.97	.95	.40	.40
	O	.73	.78	.96	.16	.24	.32
	S	-0.35	.61	.41	1.03	.59	.57
Pattern Recogni-tion	N	.50	.68	.87	.75	.36	.23
	O	.66	.66	.87	.53	.22	.28
	S	-0.35	.60	.25	.82	.44	.38

TABLE 2. Results of Analysis of Covariance

Baseline as the 1st covariate. Log of Alpha, Beta & Beta/alpha activity by subject type and task (N = normal, O = oral, S = signer) Average of two replication.

Task	Sub type	Log Alpha Left Hem.	Log Alpha Right Hem.	Log Beta Left Hem.	Log Beta Right Hem.	Log (Beta/alpha) Left Hem.	Log (Beta/alpha) Right Hem.
Mooney Faces	N	.57	.65*	.78	.87*	.37	.40*
	O	.65	.65*	.82	.45*	.30	.35*
	S	.18	.50*	.60	.95*	.53	.58*
Patern Recogni-tion	N	.50	.62*	.62	.66	.34	.24**
	O	.56	.53*	.71	.36	.28	.30**
	S	.19	.53*	.50	.70*	.39	.39**

*P<0.01, ** P<0.05

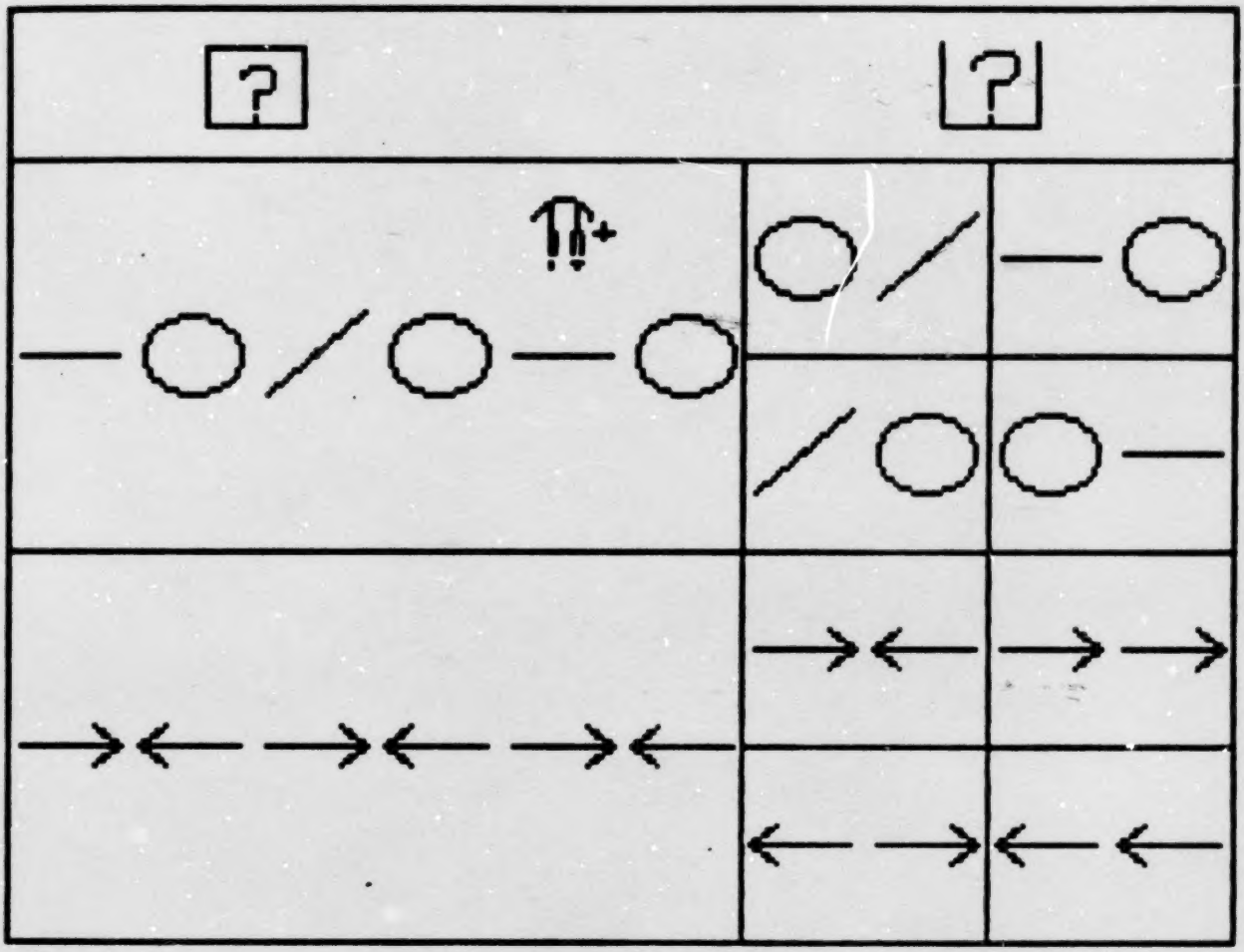
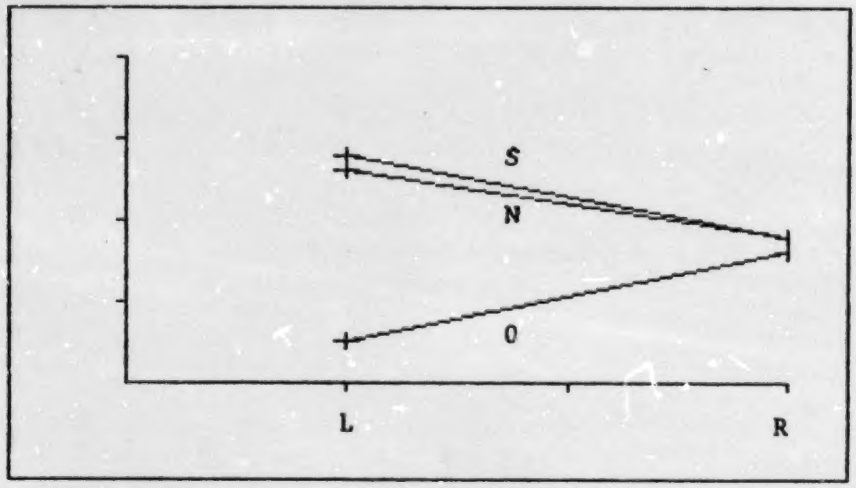
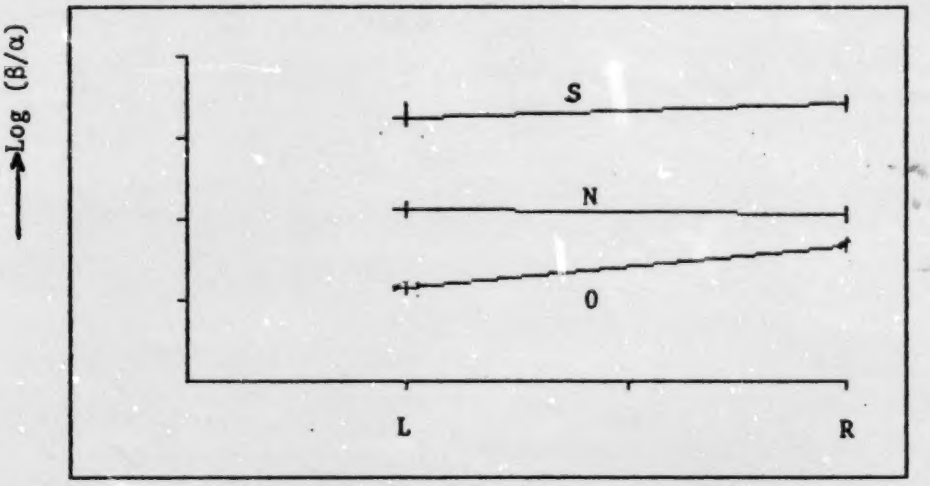


Figure 1. Pattern recognition task

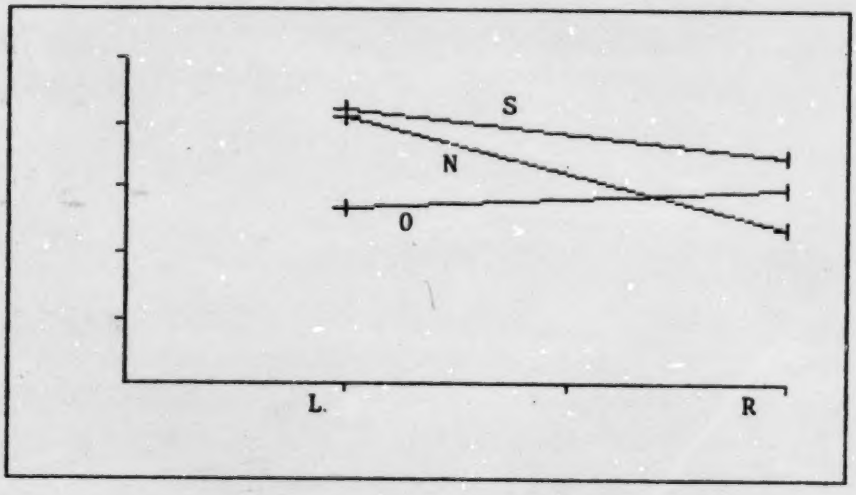


S = signers
N = normals
O = orals

Base line



Mooney faces



Pattern recognition

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Figure 2. Log (β/α) activity over left (L) and right (R) hemisphere